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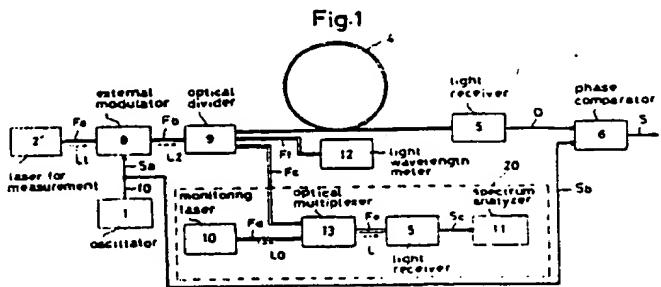
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### (54) Measurement method of dispersion characteristics of an optical fiber.

(57) In measurement method of dispersion characteristics of an optical fiber 4, a laser for measurement 2' connected to one end of the fiber 4 and variable in output light wavelength and an oscillator 1 for modulating a measurement light signal L1 sent out from the laser 2' are provided. The modulation frequency of the output from the oscillator 1 is used as an reference electric signal Sa. A measuring light signal L2 obtained through the modulator 8 and transmitted through the fiber 4 is converted into an measuring electric signal D. And the characteristics is measured from the phase difference between the reference electric signal Sb and the measuring electric signal D, wherein an external modulator 8, an optical divider 9 and a monitoring section 20 are provided. The modulator 8 modulates the measuring light signal L1 sent out from the laser 2' and having a narrow spectral lin width. The divider 9 divides the output light signal L2 from the modulator 8, at a prescribed ratio. The measuring light signal L2 obtained through the modulator 8 is multiplexed with

output light signal from a laser for monitoring 10 by the section 20 to generate a beat to measure the oscillation wavelength of the laser for measurement 2' through optical heterodyne detection. And the characteristics is measured while the result of the measurement of the oscillation wavelength is compared with that of the measurement of the phase difference.

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### Measurement method of dispersion characteristics of an optical fiber

The present invention relates to a measurement method of the dispersion characteristics of an optical fiber to a light signal transmitted therein.

Since a laser which is a light source for emitting a light signal to be transmitted through an optical fiber for communication has a widely-spread frequency spectrum and the optical fiber has dispersion characteristics, the waveform of the light signal transmitted through the optical fiber from one end thereof and received at the other end thereof has a distortion even if the proper light signal is launched into the optical fiber at the transmitter end and thereof. For that reason, there is a problem that the light signal is not received well at the receiver end of the optical fiber. Therefore, it is necessary to grasp the dispersion characteristics of the optical fiber in designing an optical communication system employing the optical fiber. Various measurement methods of the dispersion characteristics have been developed.

FIG. 3 shows a block diagram of a conventional measurement method of the dispersion characteristics of an optical fiber. Shown in FIG. 3 are an oscillator 1 for supplying electrical modulation signals  $S_1, S_2, \dots$  and  $S_N$  for laser for measurement  $2_1, 2_2, \dots$  and  $2_N$  and an electric reference signal  $S_{N+1}$  for a phase comparator 6, the laser for measurement which emit N light signals of different wavelengths in wavelength bands for measurement, an optical switch 3 for sequentially changeovering the output light signals from N numbers of the laser for measurement  $2_1, 2_2, \dots$   $2_N$ , the optical fiber 4 to be measured, a light receiver 5 by which a intensity-modulated light signal coming out from the optical fiber 4 is converted into an demodulated electrical signal D, the phase comparator 6 for detecting the phase difference between the electric demodulated electrical signal D and the reference electrical signal  $S_{N+1}$ , output signal S corresponding to the difference, and optical fiber  $F_1, F_2, \dots$  and  $F_N$ . The output light signals from the laser for measurement  $2_1, 2_2, \dots$  and  $2_N$  are subjected to intensity modulation based on the modulation frequency  $F_0$  of the oscillator 1, and are then sent to the optical fiber 4 through the other optical fibers  $F_1, F_2, \dots$  and  $F_N$  and the optical switch 3 so that the light signals enter one after another into the optical fiber 4. The light receiver 5 sequentially receives the light signals transmitted through the optical fiber 4 and converts the signals into the electrical signals  $S_1, S_2, \dots$  and  $S_N$  which are the demodulated electrical signals D. The phase differences between the reference electrical signal  $S_{N+1}$  and the demodulated electrical signals D are sequentially detected by the phase comparator 6 to measure the dispersion character-

istics of the optical fiber 4. However, since the light signals and the reference electrical signal  $S_{N+1}$  are transmitted through mutually different media to perform the measurement as shown in Fig.3, the fluctuation in the phases of the demodulated electrical signals D, which is caused when the optical fiber 4 to be measured expands or contracts due to the change in the temperature or the like, cannot be prevented from affecting the result of the measurement. This is a problem.

FIG.4 shows a block diagram of another conventional measurement method of the dispersion characteristics of an optical fiber 4. In the method, an optical reference signal and measuring light signals are transmitted through the optical fiber 4. A light signal generated by a reference laser  $2_0$  and having a wavelength of  $1.3\mu$ , which is nearly equal to the zero-dispersion wavelength of the optical fiber 4, is modulated at a frequency  $f_0$  so that the optical reference signal is obtained. Light signals generated by laser for measurement  $2_1, 2_2, \dots$  and  $2_N$  are modulated at the frequency  $f_0$  so that the measuring light signals are obtained. The measuring light signals are sequentially sent to an optical multiplexer 13 through an optical switch 3 so that each of the signals is multiplexed with the optical reference signal by the multiplexer 13, the output light signal from which is transmitted through the optical fiber 4 and received by an optical demultiplexer 7 which demultiplexes the received light signal into the optical reference signal and the measuring light signal which are converted into demodulated electrical signals Da and Db by light receivers 5a and 5b, respectively. Since the wavelength of the output light signal from the laser for reference  $2_0$  is nearly equal to the zero-dispersion wavelength of the optical fiber 4, the signal is hardly affected by the dispersion characteristics of the fiber. The output light signals from both the laser for reference  $2_0$  and the laser for measurement  $2_1, 2_2, \dots$  and  $2_N$  are equally affected by the expansion and contraction of the optical fiber 4. The demodulated electrical signals Da and Db are differentially multiplexed with each other by a phase comparator 6. As a result, the dispersion characteristics of the optical fiber 4 can be measured without being affected by the expansion and contraction of the fiber. However, since direct modulation is performed for the laser for reference  $2_0$  and the laser for measurement  $2_1, 2_2, \dots$  and  $2_N$ , a spectral spread, which is affected by the dispersion characteristics of the optical fiber 4, is caused. For that reason, it is difficult that the dispersion characteristics of the fiber 4 are measured with a high resolution. This is a problem.

Although the wavelengths of the output light signals from the laser for measurement  $2_1, 2_2, \dots$  and  $2_N$  are separately measured in advance to determine the dispersion characteristics of the optical fiber 4 on the basis of the measured wavelengths, the wavelengths change due to ambient conditions such as temperature so that it is difficult to accurately measure the wavelengths. For that reason, there is another problem that the influence of the dispersion characteristics of the optical fiber 4 cannot be accurately compensated by using a dispersion compensation circuit having a property inverse to the dispersion characteristics of the fiber in the intermediate frequency band or the baseband.

The present invention was made in order to solve the abovementioned problems.

Accordingly, it is an object of the present invention to provide a method in which the dispersion characteristics of an optical fiber are accurately measured with a high resolution. In the method, a semiconductor laser such as a distribute feedback semiconductor laser and a distribute reflector semiconductor laser, which is good in single longitudinal mode oscillation and has a narrow spectral linewidth, is used as a light source. The wavelength of the output light signal from the laser can be adjusted. Besides, an external modulator is used for optical intensity modulation. Consequently, the spectral spread of the output light signal from the semiconductor laser unit is suppressed. The wavelength of the output light signal from the laser is measured by a monitoring system employing optical heterodyne detection. As a result, the dispersion characteristics of the optical fiber can be accurately measured with the high resolution. For that reason, the present invention can be widely applied to the design of a dispersion compensation circuit for coherent light communication or to the like. The invention will now be more particularly described, by way of example, with reference to the accompanying drawings, in which:-

FIG. 1 shows a block diagram of an optical fiber dispersion characteristics measurement method which is an embodiment of the present invention;

FIG.2 shows a block diagram of an optical fiber dispersion characteristics measurement method which is another embodiment of the present invention;

FIG.3 shows a block diagram of a conventional optical fiber dispersion characteristics measurement method; and

FIG.4 shows a block diagram of another conventional optical fiber dispersion characteristics measurement method which is not affected by the expansion and contraction of a measured optical fiber.

Embodiments of the present invention are hereafter described in detail with reference to the drawings attached hereto.

FIG.1, shows a block diagram of a measurement method of the dispersion characteristics of an optical fiber 4. The method is one of the embodiments. In the method, an oscillator 1, a laser for measurement 2', light receivers 5 and 5c, a phase comparator 6, an external modulator 8, an optical divider 9, a laser for monitoring 10, a spectrum analyzer 11, a light wavelength meter 12, an optical multiplexer 13 and optical fibers Fc, Fd, Fe and Ff are disposed. The laser for measurement 2' is a distribute feedback semiconductor laser or a distribute reflector semiconductor laser. The external modulator 8 and an electrical modulation signal Sa supplied from the oscillator 1 act together so that a measuring light signal L1 emitted from the laser for measurement 2' and transmitted through an optical fiber Fa undergoes intensity modulation without increasing the spectrum width of the light signal. A measuring light signal L2 sent out from the external modulator 8 and transmitted through an optical fiber Fb is divided into three light signals at an appropriate ratio by the optical divider 9. The laser for monitoring 10 serves so that the wavelength of the measuring light signal L1 emitted from the laser for measurement 2' is measured through optical heterodyne detection. The spectrum analyzer 11 serves to monitor the difference between the wavelength of the output light signal from the laser for measurement 2' and that of the output light signal from the laser for monitoring 10. The light wavelength meter 12 roughly measures the wavelength of the output light signal from the laser for measurement 2' to determine the wavelength of the output light signal from the laser for monitoring 10. An electrical reference signal Sb is supplied from the oscillator 1 to the phase comparator 6. An electrical intermediate frequency signal Sc is supplied from the light receiver 5c to the spectrum analyzer 11. A monitoring section 20, which is one of the features of the invention and performs the measurement based on the optical heterodyne detection, is composed of laser for monitoring 10, the optical multiplexer 13, the light receiver 5c and the spectrum analyzer 11. The laser for measurement 2' is the distribute feedback semiconductor laser or the distribute reflector semiconductor laser, which is good in single longitudinal mode oscillation and narrow spectral linewidth. Since the output light signal from the laser for measurement 2' is modulated by the external modulator 8, the spectral linewidth of the output light signal is not affected by the dispersion characteristics of the optical fiber 4. For that reason, the influence of the spectral spread of the output light signal from the laser 2' upon the measurement of the dispersion

characteristics of the optical fiber 4 is reduced.

Although the laser for measurement 2' and the external modulator 8 are separately provided in the laser and the modulator may be integrated with each other.

The wavelength of the measuring light signal L1 emitted from the laser for measurement 2' is measured by the light wavelength meter 12. The driving electrical current or temperature of the laser for monitoring 10 of the monitoring section 20 is then controlled so that the difference between the wavelength of the output light signal from the laser and that of the output light signal L1 from the laser for measurement 2' is made small enough. One of the measuring light signals L2 divided by the optical divider 9 and monitoring light signal L0 divided by the optical divider 9 and a laser for monitoring 10 of the monitoring section 20 is then controlled so that the difference between the wavelength of the output light signal from the laser and that of the output light signal L1 from the laser for measurement 2' is made small enough. One of the measuring light signals L2 divided by the optical divider 9 and a monitoring light signal L0 emitted from the monitoring laser 10 are multiplexed with each other by the optical multiplexer 13 so that a beat signal L is generated from the signals L2 and L0. The beat signal L is photoelectrically converted into the electrical intermediate frequency signal Sc by the light receiver 5c. The signal Sc is observed by the spectrum analyzer 11. After that, the wavelength of the measuring light signal L1 from the laser for measurement 2' is gradually changed. The change in the wavelength of the signal L1 is observed by the spectrum analyzer 11 starting with the first wavelength of the signal. Besides, the output signal from the phase comparator 6 is measured. As a result, the dispersion characteristics of the optical fiber 4 can be accurately measured with a high resolution.

When the difference between the wavelength of the output light signal from the laser for measurement 2' and that of the output light signal from the monitoring laser 10 exceeds the measurement bandwidth of the light receiver 5c, it becomes impossible that the change in the wavelength of the output light signal from the laser for measurement 2' from the initial value of the wavelength, is measured. If the change is to be measured in such a case, the wavelength of the output light signal from the laser for monitoring 10 is caused to approach that of the output light signal from the laser for measurement 2' when the difference between both the wavelengths has become a certain value, so that the frequency of the electrical intermediate frequency signal Sc is lowered, then measuring the change. By repeating such a process, the dispersion characteristics of the optical fiber 4 can be

accurately measured with a high resolution in a wide range.

FIG. 2 shows a block diagram of a measurement method of the dispersion characteristics of an optical fiber 4. The method is the other of the embodiments. Since a reference laser is not provided in the preceding embodiment, the expansion and contraction of the optical fiber 4 cannot be prevented from affecting the result of the measurement of the dispersion characteristics of the fiber 4, for the above-mentioned reason. In the method shown in FIG. 2, a reference light signal obtained on the basis of the output light signal L3 from a laser for reference 2" is transmitted through the optical fiber 4, and a monitoring section 20 employing optical heterodyne detection is provided at the signal reception end of the fiber 4 so as to perform measurement at the far end. The reference light signal L3 from the laser for reference 2" and the measuring light signal L1 from a laser for measurement 2' are modulated into a reference light signal L4 and a measuring light signal L2 by external modulators 8a and 8b, respectively as same as the conventional art Fig. 4. An optical demultiplexer 7 and light receivers 5a and 5b are used to obtain demodulated signals Da and Db. Other optical fibers Fg and Fh are provided.

In the method shown in FIG. 2, the output light signal L3 from the laser for reference 2" is subjected to external modulation by the external modulator 8a. However, since the wavelength of the output light signal L3 from the laser for reference 2" is near the zero-dispersion wavelength of the optical fiber 4, which is 1.3 μm, the signal does not necessarily need to be subjected to the external modulation but may be subjected to direct modulation. In contrast with that, the output light signal L1 from the laser for measurement 2' needs to be subjected to external modulation by the external modulator 8b, because the wavelength of the signal L1 is near the lowloss wavelength of the fiber 4, which is 1.55 μm.

Thus, the present invention is possible to control oscillation wavelength as a measuring light source and use narrow spectral linewidth laser of a distributed feedback semiconductor laser or a distributed reflector semiconductor laser having the property of single longitudinal mode oscillation. By employing an external modulation for light intensity modulation, it is possible to make light occupying narrow bandwidth for the measurement. Furthermore, by means optical heterodyne detection as monitoring means of oscillating wavelength, the dispersion characteristics of the optical fiber can be accurately measured with the high resolution.

Accordingly, the present invention is able to

adapt widely in designing the dispersion compensation circuit for coherent optical communication. So the effect will bring very large merits.

### Claims

1. A measurement method of the dispersion characteristics of an optical fiber 4, in which a laser 2 for measurement connected to one end of said fiber and variable in output light wavelength and an oscillator 1 for modulating a measuring light signal L1 sent out from said laser 2 are provided; the modulation frequency of the output from said oscillator is used as a reference electrical signal Sb; a measuring light signal L2 obtained through said modulator 8 and transmitted through said fiber 4 is converted into a measuring electrical signal D; and said characteristics are measured from the phase difference between said reference electrical signal Sb and said measuring electrical signal D, wherein an external modulator 8, an optical divider 9 and a monitoring section 20 are provided; said modulator modulates said measuring light signal sent out from said laser and having a narrow spectral linewidth; said divider divides the output light signal L2 from said modulator, at a prescribed ratio; said measuring light signal obtained through said modulator is multiplexed with the output light signal from a laser 10 for monitoring by said section 20 to generate a beat to measure the oscillation wavelength of said laser 2 for measurement through optical heterodyne detection; and said characteristics are measured while the result of the measurement of said oscillation wavelength is compared with that of the measurement of said phase difference.

2. A measurement method of dispersion characteristics of an optical fiber 4, in which a measuring light signal L2 obtained by modulating the output light signal from a laser 2 for measurement and the output light signal L4 from a laser 2" for reference are transmitted through said fiber from one end thereof so that an outgoing light signal is divided into signals which are converted into a measuring electrical signal Db and a reference electrical signal Da, respectively; and said characteristics are measured from the phase difference between said measuring electrical signal and said reference electrical signal, wherein external modulators 8a, 8b, an optical multiplexer 13, an optical divider 9, an optical wavelength meter 12 and a monitoring section 20 are provided; said output light signal from laser for measurement which is a semiconductor laser and generates said output light signal having a narrow spectral linewidth, and said output light signal from said laser for reference, which is a semiconductor laser

and generates said output light signal having a narrow spectral linewidth, are modulated by said modulators 8a, 8b so that said measuring light signal L2 and said reference light signal L4 are sent out from said modulators, respectively; said multiplexer 13 multiplexes said measuring light signal L2 and said reference light signal L4 with each other; said divider 9 divides said outgoing light signal at a prescribed ratio; said meter 12 is connected to one end of said divider to roughly measure the wavelength of said measuring light signal; and the output light signal from a laser 10 for monitoring, the oscillation wavelength of which is adjusted on the basis of the result of the measurement by said light wavelength meter, and said measuring light signal are multiplexed with each other by said section 20 to generate a beat to accurately measure the wavelength of said measuring light signal through optical heterodyne detection.

3. A method according to the Claim 2, wherein the reference light signal is obtained by subjecting the output signal from the laser for reference to direct modulation; and the measuring light signal is obtained by modulating the output light signal from the laser for measurement through the external modulator.

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Fig.1

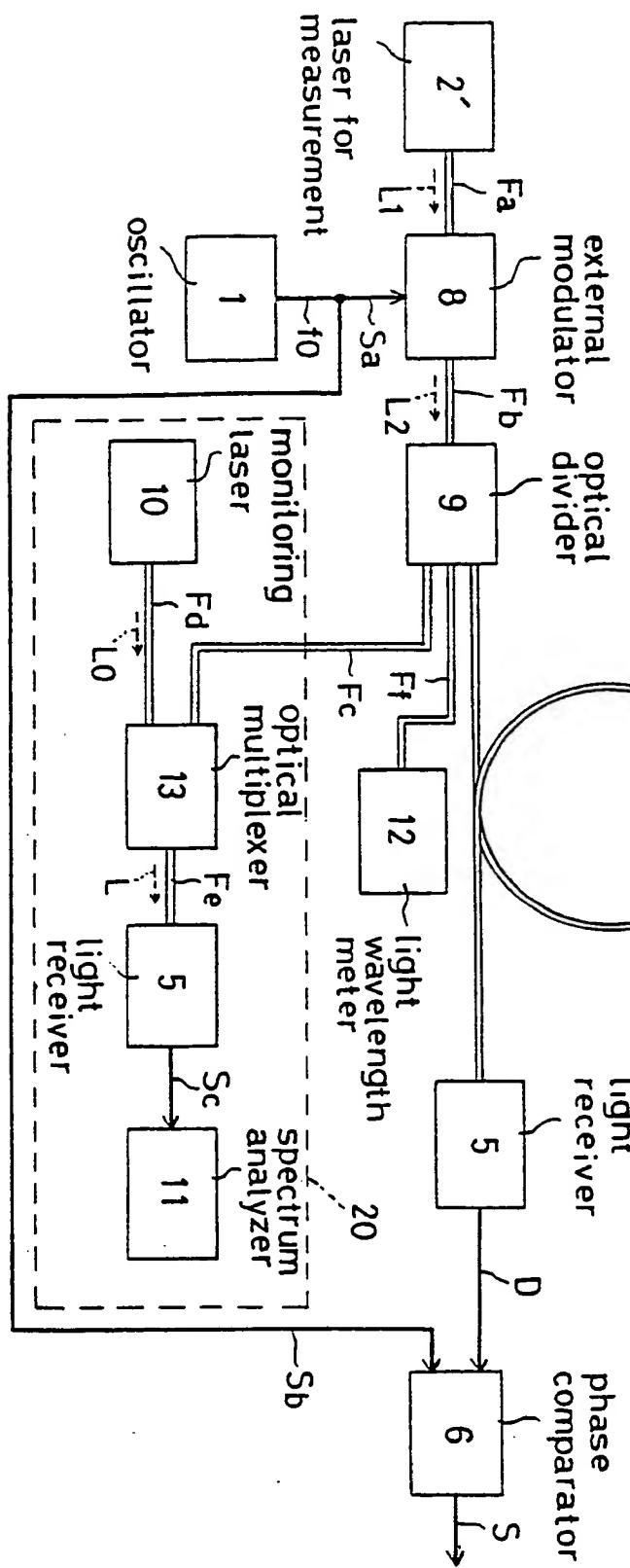
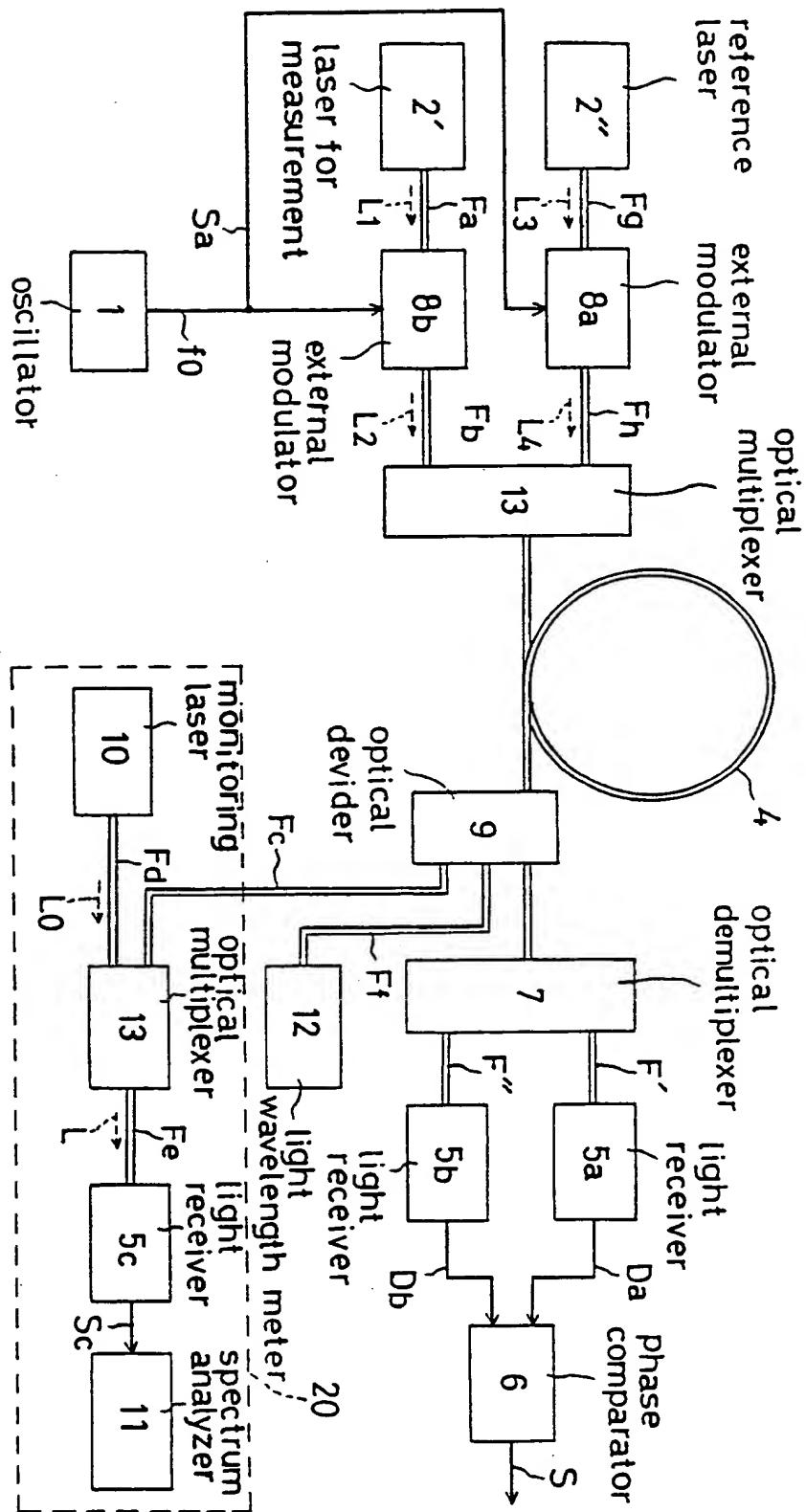
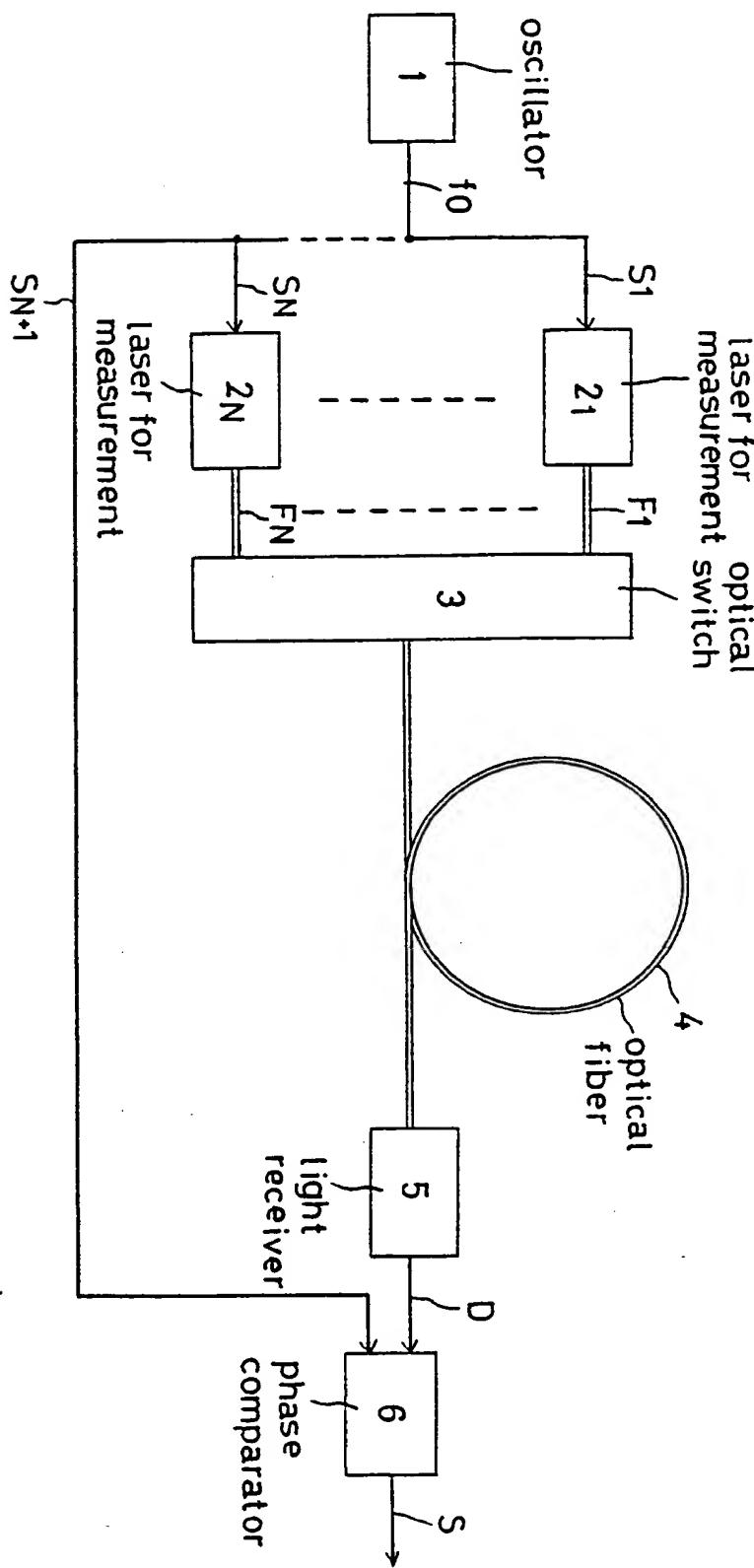


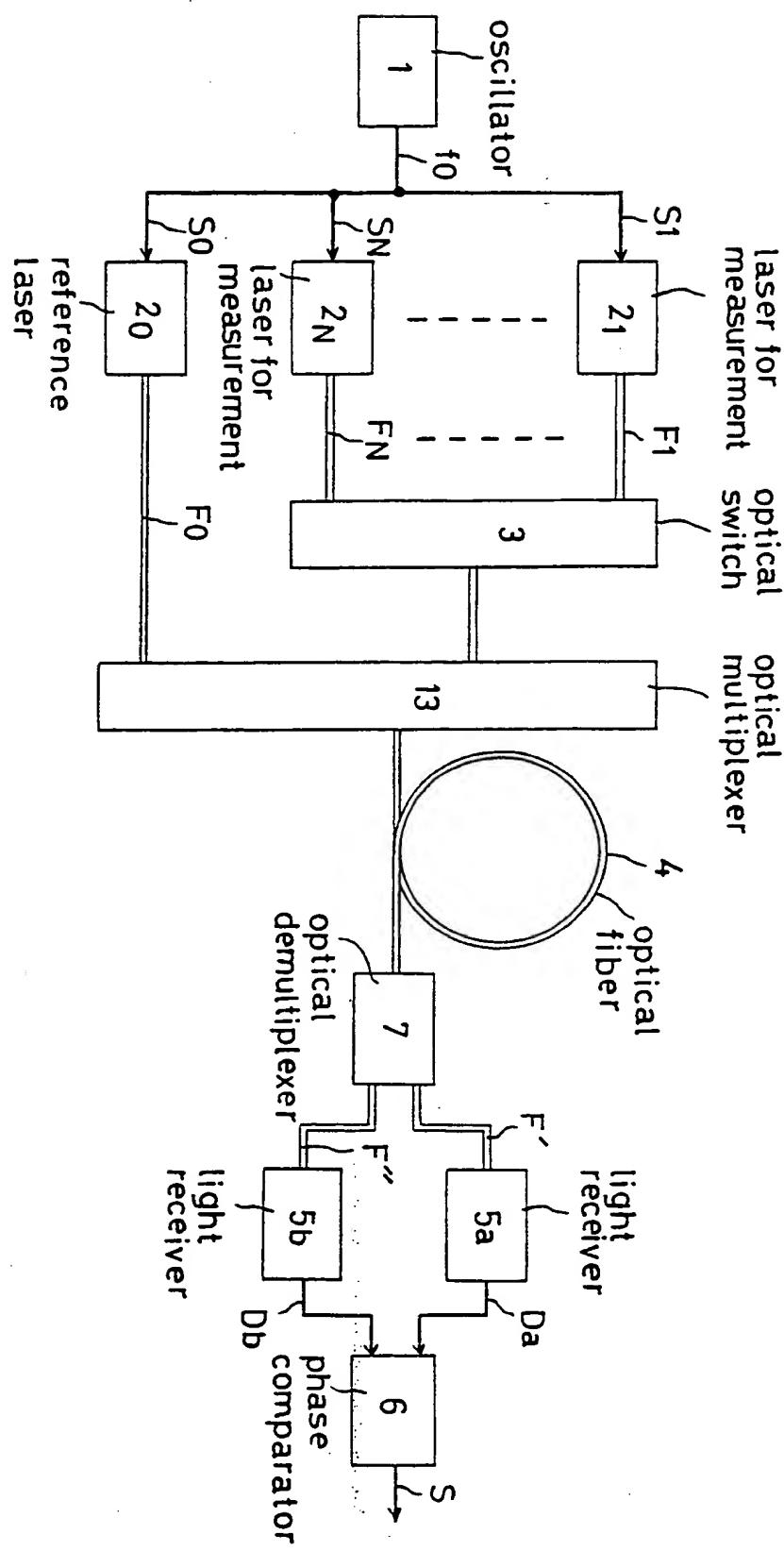
Fig.2



**Fig.3**  
PRIOR ART



**Fig.4**  
PRIOR ART





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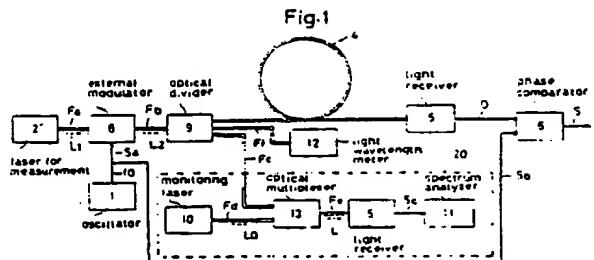
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#### **Measurement method of dispersion characteristics of an optical fiber.**

In measurement method of dispersion characteristics of an optical fiber 4, a laser for measurement 2 connected to one end of the fiber 4 and variable in output light wavelength and an oscillator 1 for modulating a measurement light signal L1 sent out from the laser 2 are provided. The modulation frequency of the output from the oscillator 1 is used as a reference electric signal Sa. A measuring light signal L2 obtained through the modulator 8 and transmitted through the fiber 4 is converted into an measuring electric signal D. And the characteristics is measured from the phase difference between the reference electric signal Sb and the measuring electric signal D, wherein an external modulator 8, an optical divider 9 and a monitoring section 20 are provided. The modulator 8 modulates the measuring light signal L1 sent out from the laser 2 and having a narrow spectral linewidth. The divider 9 divides the output light signal L2 from the modulator 8, at a prescribed ratio. The measuring light signal L2 obtained through the modulator 8 is multiplexed with output light signal from a laser for monitoring 10 by

the section 20 to generate a beat to measure the oscillation wavelength of the laser for measurement 2' through optical heterodyne detection. And the characteristics is measured while the result of the measurement of the oscillation wavelength is compared with that of the measurement of the phase difference.





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# EUROPEAN SEARCH REPORT

Application Number

EP 89 30 4690

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A	REVIEW OF SCIENTIFIC INSTRUMENTS, vol. 50, no. 3, March 1979, pages 343-346, American Institute of Physics, New York, US; A. SUGIMURA et al.: "Wavelength dispersion of optical fibers directly measured by "difference method" in the 0.8-1.6 mum range" * Whole document * ---	1,2	G 01 M 11/00
A	OPTICS LETTERS, vol. 11, no. 5, May 1986, pages 330-332, New York, US; T. KANADA et al.: "Single-mode fiber dispersion measurements using optical sampling with a mode-locked laser diode" * Whole document * ---	1,2	
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The present search report has been drawn up for all claims			
Place of search	Date of completion of the search	Examiner	
THE HAGUE	17-07-1990	VAN ASSCHE P.O.	
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